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The Effects of a Vector-like Doublet as The Fourth Generation to R_b

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Abstract

We study the effects of a vector-like SU(2) doublet quarks as the fourth generation on R_b and R_c. By considering the constraint from the experimental data of forward-backward asymmetry, A^b_{FB} and A^c_{FB},as well as FCNC among light quarks, we show that there is an allowed region of parameters for R_b but not for R_c.

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1 Introduction

The standard model(SM) is consistent with almost all of the experiments. Most of the experiments are consistent with the predictions of SM with sufficient accuracy. However, the recent experimental data at LEP shows that there are the deviations from the standard model prediction in the Z boson partial width ratios $R_b = \Gamma[Z \to b\bar{b}]/\Gamma[Z \to hadrons]$ and R_c. The experimental values $R_b = 0.2219 \pm 0.0017$ and $R_c = 0.1540 \pm 0.0074$ have already been different from the values $R_b^{SM} = 0.2157$ and $R_c^{SM} = 0.1722$ which are predicted by SM with top quark mass $m_t = 175GeV$[1]. If these deviations show the existence of new physics, we must examine all of the possibility of beyond SM.

At present, the predictions for R_b and R_c in many beyond the standard models are compared with the experiments, any of them can not explain the deviations [2]. In minimal supersymmetric model, in order to explain the deviation of the R_b there must be light chargino and top squark[3]. In the extended technicolor model(ETC), in the works [4] it is shown that the diagonal extended technicolor(ETC) interaction may solve the problem. However, the effect contribute to T parameter, too[5]. If the contribution of the diagonal interaction to Zbb vertex is large enough to cancel the other corrections for the Zbb vertex, T is unacceptably large.

In those works mentioned above, the corrections to Zbb vertex from loop contribution of new particles are mainly studied. In this paper, we consider the shift of Z coupling at tree level in the context of the non-trivial extension of quark sector into the forth generation. The shift comes from the flavor mixing like CKM[6] matrix. In this work, we discuss the effect of a vector-like SU(2)doublet quarks as the fourth generation to the Zbb vertex. In this model the right-handed Z coupling differs from that of the SM. Hence, the Z decay widths are different from those of the SM at tree level. The effects of the vector-like doublet quarks as the third generation, were already studied in Ref.[7].

However, because they assume that the vector like quarks are the third generation, their model can not satisfy the constraint from the forward-backward asymmetry, A^b_{FB}.(See section 2.) Therefore, we study a vector-like doublet quarks as the forth generation.

This paper is developed as following. In section 2, we discuss the model including a vector-like doublets as the forth generation. In section 3, the effects on R_b and R_c is shown in the simple case that the flavor mixing occurs only between the third and the forth generation. In section 4, we show the relation between the mixing angle and mass of new quarks. Section 5 is devoted to the conclusion.

2 The Model

First, we study the effects of new fermions which are transformed in a vector-like way under the electro-weak symmetry $SU(2)_L \otimes U(1)_Y$. The SU(2) and hypercharge of ordinary fermions Q and new vector-like fermions Q' are assigned in the following way.

$$Q^i_L = \begin{pmatrix} u^i \\ d^i \end{pmatrix}_L \sim (2, \frac{1}{3}), u^i_R \sim (1, \frac{4}{3}), d^i_R \sim (1, -\frac{2}{3}),$$

$$Q'_L = \begin{pmatrix} u' \\ d' \end{pmatrix}_L \sim (2, \frac{1}{3}),$$
$$Q'_R = \begin{pmatrix} u' \\ d' \end{pmatrix}_R \sim (2, \frac{1}{3}).$$

Because the vector-like fermions are SU(2) doublet, the left-handed and right-handed chiralities have the same charge under $SU(2)_L$ transformation.

The neutral current interactions of fermions can be written as

$$\mathcal{L} = -\frac{g}{2cos\theta_w} \sum_i [L_i \bar{Q}^i_L \gamma^\mu Q^i_L + R_i \bar{Q}^i_R \gamma^\mu Q^i_R] Z_\mu, \tag{1}$$

where $Q^i_{L(R)}$ show left(right)-handed quark doublet and i shows the generation number. For ordinary quarks, the coefficients of couplings L_i and R_i are

$$L_U = L_{ui} = 1 - \frac{4}{3}\sin^2\theta_w, \tag{2}$$

$$R_U = R_{ui} = -\frac{4}{3}\sin^2\theta_w, \tag{3}$$

for up sector and

$$L_D = L_{di} = -1 + \frac{2}{3}\sin^2\theta_w, \tag{4}$$

$$R_D = R_{di} = \frac{2}{3}\sin^2\theta_w, \tag{5}$$

for down sector, where θ_w is Weinberg angle. For the vector-like quarks, the couplings for right-handed fermions are the same as the left-handed ones, that is,

$$R'_U = L_U, \tag{6}$$

$$R'_D = L_D. \tag{7}$$

For the case that the fourth generation is a vector-like doublet fermions, the neutral current are explicitly given by the following equation.

$$\begin{aligned}
-\frac{g}{2cos\theta_w} \quad [\quad & (\,\bar{u}^1 \quad \bar{u}^2 \quad \bar{u}^3 \quad \bar{u}^4\,)_L \begin{pmatrix} L_U & & & \\ & L_U & & \\ & & L_U & \\ & & & L_U \end{pmatrix} \gamma^\mu \begin{pmatrix} u^1 \\ u^2 \\ u^3 \\ u^4 \end{pmatrix}_L \\
+ \quad & (\,\bar{u}^1 \quad \bar{u}^2 \quad \bar{u}^3 \quad \bar{u}^4\,)_R \begin{pmatrix} R_U & & & \\ & R_U & & \\ & & R_U & \\ & & & R'_U \end{pmatrix} \gamma^\mu \begin{pmatrix} u^1 \\ u^2 \\ u^3 \\ u^4 \end{pmatrix}_R \\
+ \quad & (\,\bar{d}^1 \quad \bar{d}^2 \quad \bar{d}^3 \quad \bar{d}^4\,)_L \begin{pmatrix} L_D & & & \\ & L_D & & \\ & & L_D & \\ & & & L_D \end{pmatrix} \gamma^\mu \begin{pmatrix} d^1 \\ d^2 \\ d^3 \\ d^4 \end{pmatrix}_L \\
+ \quad & (\,\bar{d}^1 \quad \bar{d}^2 \quad \bar{d}^3 \quad \bar{d}^4\,)_R \begin{pmatrix} R_D & & & \\ & R_D & & \\ & & R_D & \\ & & & R'_D \end{pmatrix} \gamma^\mu \begin{pmatrix} d^1 \\ d^2 \\ d^3 \\ d^4 \end{pmatrix}_R \quad].
\end{aligned} \tag{8}$$

Note that only the right-handed coupling for the forth generation of quark differs from those of the other three generations. With paying attention to the difference of the right-handed couplings, we transform the bases from weak eigenstate to mass eigenstate by the

unitary transformation.

$$
\begin{aligned}
-\frac{g}{2cos\theta_w} \quad [\quad & (\bar{u} \quad \bar{c} \quad \bar{t} \quad \bar{u'})_L \, L_U \gamma^\mu \begin{pmatrix} u \\ c \\ t \\ u' \end{pmatrix}_L \\
+ \quad & (\bar{u} \quad \bar{c} \quad \bar{t} \quad \bar{u'})_R \, \{R_U + V_{LU}^\dagger \begin{pmatrix} 0 & & & \\ & 0 & & \\ & & 0 & \\ & & & R'_U - R_U \end{pmatrix} V_{LU}\} \gamma^\mu \begin{pmatrix} u \\ c \\ t \\ u' \end{pmatrix}_R \\
+ \quad & (\bar{d} \quad \bar{s} \quad \bar{b} \quad \bar{d'})_L \, R_U \gamma^\mu \begin{pmatrix} d \\ s \\ b \\ d' \end{pmatrix}_L \qquad (9) \\
+ \quad & (\bar{d} \quad \bar{s} \quad \bar{b} \quad \bar{d'})_R \, \{R_D + V_{RD}^\dagger \begin{pmatrix} 0 & & & \\ & 0 & & \\ & & 0 & \\ & & & R'_D - R_D \end{pmatrix} V_{RD}\} \gamma^\mu \begin{pmatrix} d \\ s \\ b \\ d' \end{pmatrix}_R \quad].
\end{aligned}
$$

In the mass eigenstates, the left-handed current dose not change but the right-handed current changes as following;

$$
g_R^U = -\frac{g}{2c_w}\{R_U + \begin{pmatrix} \mid V_{14} \mid^2 & V_{14}^* V_{42} & V_{14}^* V_{43} & V_{14}^* V_{44} \\ V_{24}^* V_{41} & \mid V_{24} \mid^2 & V_{24}^* V_{43} & V_{24}^* V_{44} \\ V_{34}^* V_{41} & V_{34}^* V_{42} & \mid V_{34} \mid^2 & V_{34}^* V_{44} \\ V_{44}^* V_{41} & V_{44}^* V_{42} & V_{44}^* V_{43} & \mid V_{44} \mid^2 \end{pmatrix}_{RU} \}, \tag{10}
$$

$$
g_R^D = -\frac{g}{2c_w}\{R_D - \begin{pmatrix} \mid V_{14} \mid^2 & V_{14}^* V_{42} & V_{14}^* V_{43} & V_{14}^* V_{44} \\ V_{24}^* V_{41} & \mid V_{24} \mid^2 & V_{24}^* V_{43} & V_{24}^* V_{44} \\ V_{34}^* V_{41} & V_{34}^* V_{42} & \mid V_{34} \mid^2 & V_{34}^* V_{44} \\ V_{44}^* V_{41} & V_{44}^* V_{42} & V_{44}^* V_{43} & \mid V_{44} \mid^2 \end{pmatrix}_{RD} \}. \tag{11}
$$

As shown in the above equations, there are FCNC among four generations in general. Because FCNC among light quarks like $Z \rightarrow ds$ are strongly constrained by the experiments, we simply suppose that there are no couplings which produce FCNC among the light quarks in this model. The model which corresponds to the simple assumption will be discussed in section 2. Before going into the model that the quark of the forth generation is vector-like doublet, let us briefly study the models that the quark of the third generation is a vector-like doublet [7] and show why those models are not consistent with the experiments. In the case that the third generation is a vector like doublet and there

is no more generations, the right-handed coupling of Z boson is

$$g_R^{(U,D)} = -\frac{g}{2c_w}\{R_{(U,D)} \pm \begin{pmatrix} | V_{13} |^2 & V_{13}^* V_{32} & V_{13}^* V_{33} \\ V_{23}^* V_{31} & | V_{23} |^2 & V_{23}^* V_{33} \\ V_{33}^* V_{31} & V_{33}^* V_{32} & | V_{33} |^2 \end{pmatrix}_{R(U,D)} \}. \tag{12}$$

From the unitarity of matrix V_R, we obtain the following constraint for the mixing of right-handed quarks.

$$| V_{13} |^2 + | V_{23} |^2 + | V_{33} |^2 = 1. \tag{13}$$

In order to avoid the FCNC among light quarks, the values of V_{13} and V_{23} must be very small. Then, by using the unitarity condition eq.(13), $| V_{33} | \sim 1$. This means that the the right handed coupling of b quark must be almost the same as that of the left-handed. However,in that case, the constraint from A_{FB} can not be satisfied. If the right handed coupling of b quark is the same as that of the left-handed one, there is no neutral axial vector current in Zbb vertex and the forward-backward asymmetry, A^b_{FB}, must disappear.

Even if we add more vector-like doublet quarks, the situation is not changed. To show this, we consider the case that the third generation and the forth generation are vector-like doublets. The right-handed coupling of Z boson to down type quarks is given by, (Here we assume that there is no FCNC among the light quarks.)

$$g_R^{(D)} = -\frac{g}{2c_w}\{R_{(D)} - \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & | V_{33} |^2 + | V_{34} |^2 & V_{33}^* V_{34} + V_{34}^* V_{44} \\ 0 & 0 & V_{34}^* V_{33} + V_{44}^* V_{43} & | V_{34} |^2 + | V_{44} |^2 \end{pmatrix}_{R(D)} \}, \tag{14}$$

where we put $V_{13} \sim V_{23} \sim V_{14} \sim V_{24} \sim 0$. From the unitarity of the matrix V_R,

$$| V_{33} |^2 + | V_{34} |^2 = 1. \tag{15}$$

Again eq.(15) show that Zbb coupling must be vector type and it contradicts with the $A^b{}_{FB}$ because of the same reason as the first case.

Hence, we consider the model in which only the forth generation is a vector-like doublet quarks.

3 A Simple Model

There are mixings among the heavy quarks but are not among the light quarks to avoid the problems of FCNC from Z couplings. The neutral couplings of the ordinary quarks are

$$\begin{aligned}
g_L^u = g_L^c &= L_U, && (16)\\
g_L^d = g_L^s = g_L^b &= L_D, && (17)\\
g_R^u &= R_U, && (18)\\
g_R^c &= R_U + {V_{RU}^{42}}^2, && (19)\\
g_R^d = g_R^s &= R_D, && (20)\\
g_R^b &= R_D - {V_{RD}^{43}}^2, && (21)
\end{aligned}$$

where V_{RU}^{42} and V_{RD}^{43} are the component of unitary matrix V_R. The difference of the sign of the V^2 between g_R^c and g_R^b come from one of the isospin. The experiment favor positive contribution for R_b and negative contribution forR_c. Then the partial width R_b and R_c is

$$\begin{aligned}
R_b^{tree} &\sim \frac{{g_L^b}^2 + {g_R^b}^2}{{g_L^u}^2 + {g_L^c}^2 + {g_L^d}^2 + {g_L^s}^2 + {g_L^b}^2 + {g_R^u}^2 + {g_R^c}^2 + {g_R^d}^2 + {g_R^s}^2 + {g_R^b}^2}\\
&\sim \frac{L_D^2 + (R_D - {V_{RD}^{43}}^2)^2}{2L_U^2 + 3L_D^2 + R_U^2 + 2R_D^2 + (R_U + {V_{RU}^{42}}^2)^2 + (R_D - {V_{RD}^{43}}^2)^2}, \qquad (22)
\end{aligned}$$

$$\begin{aligned}
R_c^{tree} &\sim \frac{{g_L^c}^2 + {g_R^c}^2}{{g_L^u}^2 + {g_L^c}^2 + {g_L^d}^2 + {g_L^s}^2 + {g_L^b}^2 + {g_R^u}^2 + {g_R^c}^2 + {g_R^d}^2 + {g_R^s}^2 + {g_R^b}^2}\\
&\sim \frac{L_U^2 + (R_U + {V_{RU}^{42}}^2)^2}{2L_U^2 + 3L_D^2 + R_U^2 + 2R_D^2 + (R_U + {V_{RU}^{42}}^2)^2 + (R_D - {V_{RD}^{43}}^2)^2}. \qquad (23)
\end{aligned}$$

Because of the minus sign of ${V_{RD}^{43}}^2$ in the g_R^b, unless the values is larger than $2 \times R_D$, the contribution from V^2 reduce the R_b. If ${V_{RD}^{43}}^2$ is larger than $2 \times R_D$ and $R_U + {V_{RU}^{42}}^2$ become smaller, R_b may be enhanced and R_c may become smaller. While, we must also examine the allowed region of these parameter V_{RU} and V_{RD} for forward-backward

asymmetry A^c_{FB} and A^b_{FB}. The values of the experiment are $A^{0,b}_{FB} = 0.0997 \pm 0.0031$ and $A^{0,c}_{FB} = 0.0729 \pm 0.0058$[1]. The prediction of SM are $A^{bSM}_{FB} = 0.1039$ and $A^{cSM}_{FB} = 0.744$ with $m_t = 175GeV$ and Higgs mass $m_H = 1TeV$. In Fig.1 and Fig.2, we plot the behavior of δA^b_{FB} and δA^c_{FB} which are shifting the SM result due to V_{RD} and V_{RU}. The formalism of the forward-backward asymmetry is

$$A^f_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B} \tag{24}$$

where σ_F and σ_B are the cross sections for the outgoing fermion, f, to go forwards or backwards relative to the direction of the incoming electron. When the center of mass, $\sqrt{s}$, is about the mass M_Z, the forward-backward asymmetry, A_{FB} is shown by the following,

$$A^f_{FB} = \frac{3}{4} A_e A_f, \tag{25}$$

where,

$$A_f = \frac{2(g_L + g_R)(g_L - g_R)}{(g_L + g_R)^2 + (g_L - g_R)^2}. \tag{26}$$

It is interesting that the value of forward-backward asymmetry do not change by replacing the g_R with $-g_R$. R_b and R_c have also the same feature. Hence, we expect that R_b and A^b_{FB} with ${V^{43}_{RD}}^2 = 2 \times R_D$ is same the values with ${V^{43}_{RD}}^2 = 0$. The range of shifting of the right-handed Z couplings must satisfy the constraint from the forward-backward asymmetry. The contribution from the shifting of the neutral couplings to the forward-backward asymmetry is

$$\delta A^b_{FB} = -\frac{3}{4} A_e (1 + A_b) \frac{4R_D({V^{43}_{RD}}^2 - 2R_D)}{(L_D + R_D)^2 + (L_D - R_D)^2}, \tag{27}$$

$$\delta A^c_{FB} = -\frac{3}{4} A_e (1 + A_c) \frac{4R_U {V^{42}_{RU}}^2}{(L_U + R_U)^2 + (L_U - R_U)^2}. \tag{28}$$

Here, we consider the contribution to A^b_{FB} is the value for the shift of ${V^{43}_{RD}}^2$ from $2 \times R_D$. In Fig.1, the behavior of the δA^b_{FB} is shown. From the experimental data, the allowed

region of δA^b_{FB} must be from - 0.0011 to - 0.0073. Then, the value of ${V^{43}_{RD}}^2$ must be smaller than about 0.38. While, in Fig.2, the behavior of δA^c_{FB} is shown. The allowed region of δA^c_{FB} must be 0.0043 $\sim$ - 0.0073. Then, the upper bound for the value of ${V^{24}_{RU}}^2$ is about 0.033. For the region satisfying the constraint from forward-backward asymmetry, we plot R_b and R_c in Fig.3 and Fig.4 in the following case of ${V^{24}_{RU}}^2$. (1) ${V^{24}_{RU}}^2 = 0.01$, (2) 0.02, (3)0.03. Here, we used the prediction of SM with $m_t = 175GeV$ and add the contribution from shifting the right-hand coupling to its values. There is a region which is satisfying both conditions for R_b and A^b_{FB} but not for R_c, A^b_{FB} and A^c_{FB}. With ${V^{34}_{RD}}^2 = 0.36$, the prediction of R_b reach to the center values of experiment. The figures show that The effect of vector-like doublet as the forth generation may explain the difference of R_b between the experiment and SM but can not explain the difference of R_c.

On the other hand the charged current and the KM matrix are

$$\mathcal{L}^{cc}_R = -\frac{g}{\sqrt{2}} (\,\bar{u} \quad \bar{c} \quad \bar{t} \quad \bar{u}'\,)_R \, V^\dagger_{RU} \begin{pmatrix} 0 & & & \\ & 0 & & \\ & & 0 & \\ & & & 1 \end{pmatrix} V_{RD} \gamma^\mu \begin{pmatrix} d \\ s \\ b \\ d' \end{pmatrix}_R W^\dagger_\mu . \tag{29}$$

For example, the KM matrix becomes

$$V^R_{KM} = \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & {V^{24}_{RU}}^* V^{43}_{RD} & {V^{24}_{RU}}^* V^{44}_{RD} \\ 0 & 0 & {V^{34}_{RU}}^* V^{43}_{RD} & {V^{34}_{RU}}^* V^{44}_{RD} \\ 0 & 0 & {V^{44}_{RU}}^* V^{43}_{RD} & {V^{44}_{RU}}^* V^{44}_{RD} \end{pmatrix} . \tag{30}$$

Note that this matrix is not unitary. In this paper, we did not discussed the effect from the right hand KM matrix. By upper discussion, we may be able to examine the value of component of the matrix. We must consider the contribution from the process like $b \to s\gamma$.

4 Flavor Mixing

We must examine whether such large mixing between b quark and the fourth down type quark is a realistic model. We consider the simple vector-like doublet model which are

assumed to mix only with the third generation[8, 9]. Without loss of generality, the quark mass terms are

$$(\,\bar{u}^3 \quad \bar{u}^4\,)_L \begin{pmatrix} m_u & 0 \\ Je^{ix} & M_V \end{pmatrix} \begin{pmatrix} u^3 \\ u^4 \end{pmatrix}_R + (\,\bar{d}^3 \quad \bar{d}^4\,)_L \begin{pmatrix} m_d & 0 \\ K & M_V \end{pmatrix} \begin{pmatrix} d^3 \\ d^4 \end{pmatrix}_R + h.c., \tag{31}$$

where M_V is a mass of vector-like quarks, J, K show mixing mass. By using the unitary transformation the mass matrix is diagonalized as following,

$$\begin{pmatrix} c_{LU} & -s_{LU}e^{-ix} \\ s_{LU}e^{ix} & c_{LU} \end{pmatrix} \begin{pmatrix} m_u & 0 \\ Je^{ix} & M_V \end{pmatrix} \begin{pmatrix} c_{RU} & -s_{RU}e^{-ix} \\ s_{RU}e^{ix} & c_{RU} \end{pmatrix} = \begin{pmatrix} m_t & 0 \\ 0 & M_u \end{pmatrix} \tag{32}$$

$$\begin{pmatrix} c_{LD} & -s_{LD} \\ s_{LD} & c_{LD} \end{pmatrix} \begin{pmatrix} m_d & 0 \\ K & M_V \end{pmatrix} \begin{pmatrix} c_{RD} & -s_{RD} \\ s_{RD} & c_{RD} \end{pmatrix} = \begin{pmatrix} m_b & 0 \\ 0 & M_d \end{pmatrix}, \tag{33}$$

where $c_{XX} = cos\theta_{XX}$ and $s_{XX} = sin\theta_{XX}$ and the θ_{XX} show the mixing angle. The masses of eigen states are

$$m_t^2 = \frac{1}{2}[m_u^2 + M_V^2 + J^2 - \sqrt{(m_u^2 + M_V^2 + J^2)^2 - 4m_u^2 M_V^2}], \tag{34}$$

$$M_u^2 = \frac{1}{2}[m_u^2 + M_V^2 + J^2 + \sqrt{(m_u^2 + M_V^2 + J^2)^2 - 4m_u^2 M_V^2}], \tag{35}$$

$$m_b^2 = \frac{1}{2}[m_d^2 + M_V^2 + K^2 - \sqrt{(m_d^2 + M_V^2 + K^2)^2 - 4m_d^2 M_V^2}], \tag{36}$$

$$M_d^2 = \frac{1}{2}[m_d^2 + M_V^2 + K^2 + \sqrt{(m_d^2 + M_V^2 + K^2)^2 - 4m_d^2 M_V^2}]. \tag{37}$$

The mixing just corresponding to V_{34}^2 are

$$s_{RU}^2 = \frac{(m_u^2 - M_V^2 + J^2)(m_u^2 + J^2 - m_t^2) + 2J^2 M_V^2}{(m_u^2 - M_V^2 + J^2)^2 - 4J^2 M_V^2}, \tag{38}$$

$$s_{RU} = \frac{M_V}{m_t} s_{LU}, \tag{39}$$

$$s_{RD}^2 = \frac{(m_d^2 - M_V^2 + K^2)(m_d^2 + K^2 - m_b^2) + 2K^2 M_V^2}{(m_d^2 - M_V^2 + J^2)^2 - 4K^2 M_V^2,} \tag{40}$$

$$s_{RD} = \frac{M_V}{m_b} s_{LD}. \tag{41}$$

In Fig. 5, we plot s_{RD}^2 as a function of K in the several case of M_V, 1TeV, and 2TeV and 3TeV. Here, we put $m_b = 5GeV$. The Figure shows that there is a region to produce large

mixing. $V_{34}^2 \sim s_{RD}^2 \sim 0.35$. It is interesting that even if the mixing for right-hand quark is very large, the left-hand one is kept very small because of eq.(41). Hence, the CKM matrix for left-handed quarks will not make a large different from SM. Since we assume a very large vector-like quark mass, the dependence to Oblique correction[10] will be small by means of decoupling[9].

5 Conclusion

We discussed the effect of vector-like doublet quarks to Z partial decay width. Under consideration of some constraint from FCNC for light quarks and forward-backward asymmetry, only model of vector-like quarks as the forth generation is allowed. We find that this model may explain the difference of R_b between the experiment and the prediction of SM but not do for R_c. We will have to consider the other contribution to R_c.

In this work, we could not do sufficiently discussion for flavor physics. If we apply this model, the contribution to $b \to s\gamma$ must be calculated.

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Figure Captions

- **Figure 1** Plotting the δA^b_{FB} as a function of ${V^D_{R34}}^2$.

- **Figure 2** Plotting the δA^c_{FB} as a function of ${V^U_{R24}}^2$.

- **Figure 3** R_b as a function of ${V^D_{R34}}^2$ for following values for ${V^U_{R24}}^2$. (1) 0.01 with a thinline, (2) 0.02 with a thickline, (3) 0.03 with s dashed thinline.

- **Figure 4** R_c as a function of ${V^D_{R34}}^2$ for following values for ${V^U_{R24}}^2$. (1) 0.01 with a thinline, (2) 0.02 with a thickline, (3) 0.03 with s dashed thinline.

- **Figure 5**s^2_{RD} as a function of mass mixing, K, for following mass M_V. (a) 1 TeV with a dashed thinline, (b) 2 TeV with a dashed thickline and (c) 3 TeV with a thickline.

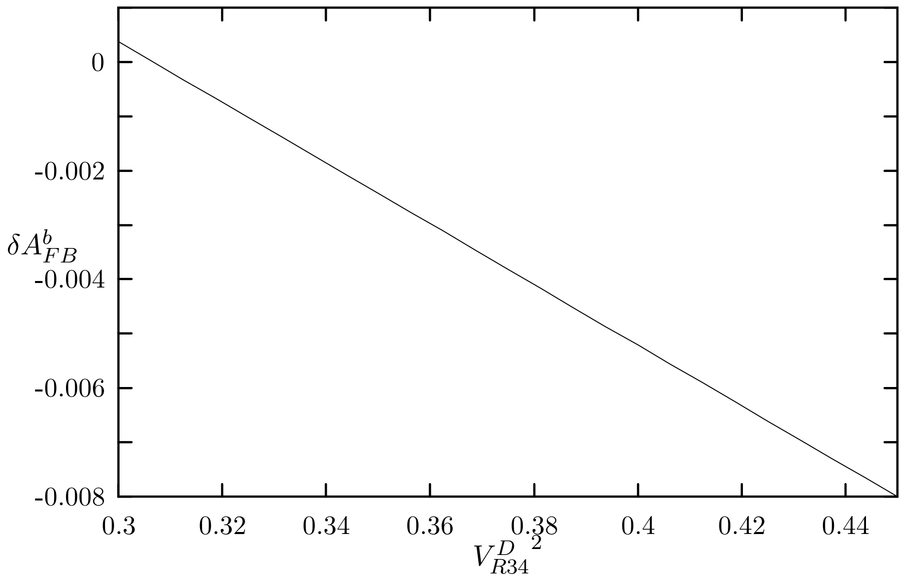

Figure 1:

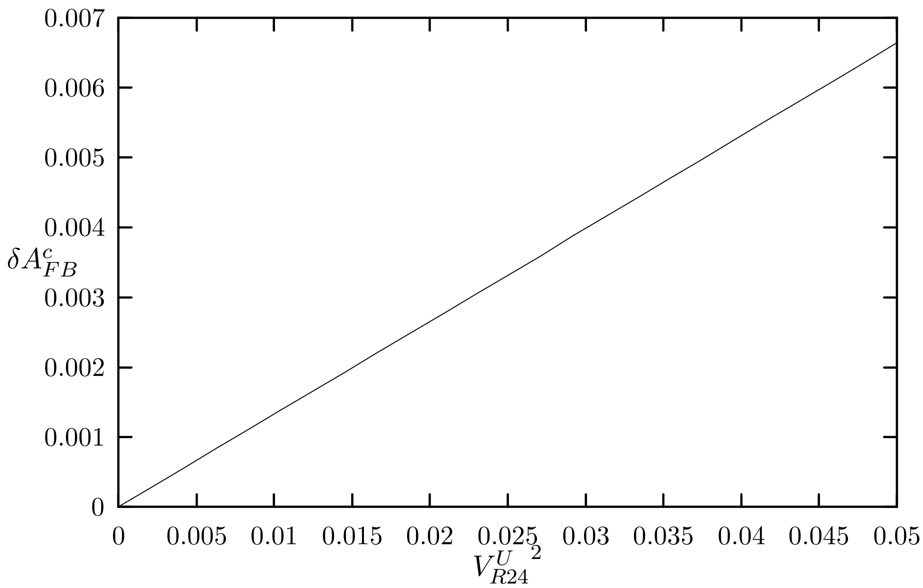

Figure 2:

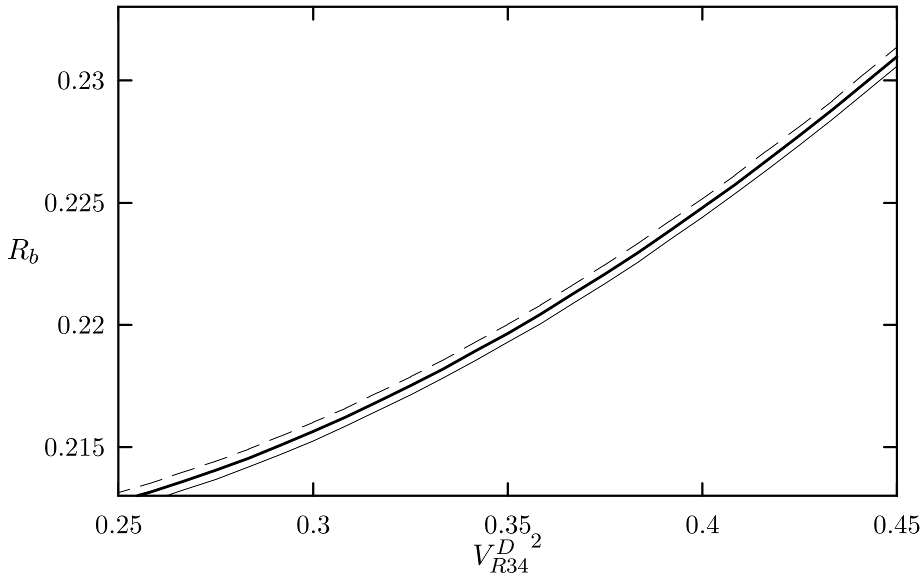

Figure 3:

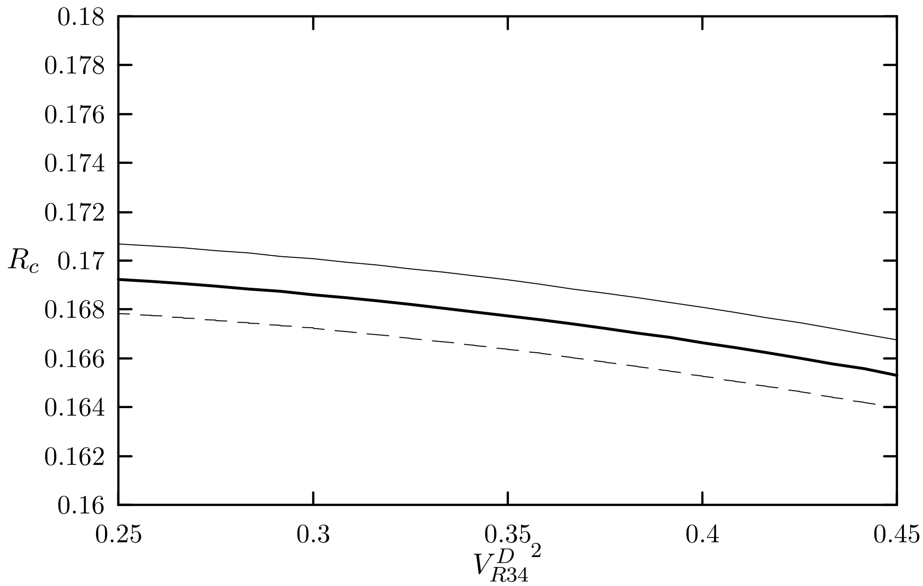

Figure 4:

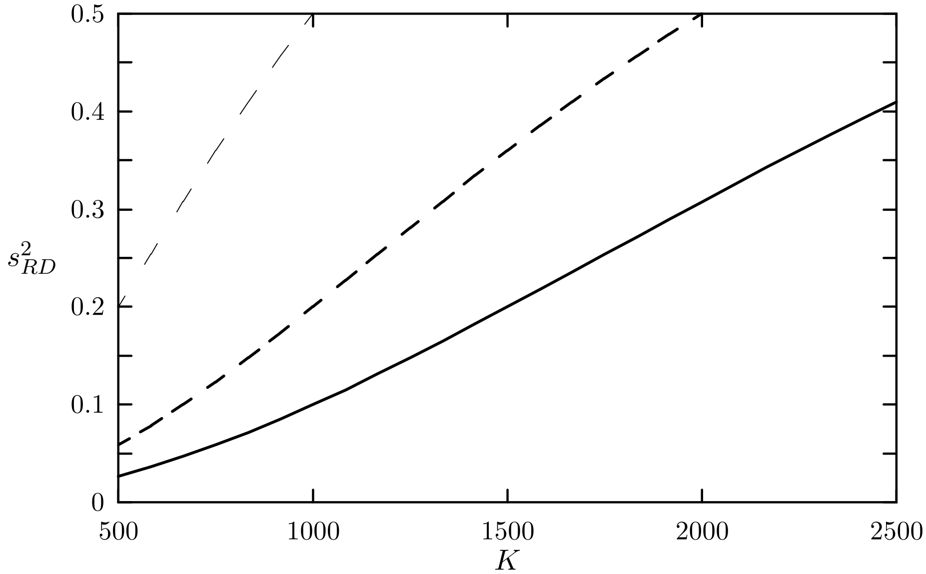

Figure 5: